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Growth and Yield Response of Hybrid Maize through Integrated Phosphorus Management

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ABSTRACT

Integrated use of organic manures and inorganic fertilizer can satiate the crop needs as an economical and environment friendly nutrient source. A field study was conducted to evaluate the growth and yield response of autumn maize to sole and integrated application of organic and inorganic phosphorus (P) sources during the year 2008 and 2009. Poultry manure and press mud as organic P and single superphosphate as inorganic phosphorus source were substituted in different ratios. Inorganic phosphorus source was substituted with 25, 50 and 75% organic source as per treatment. Plots without any P source were maintained as control. Data on maize growth and yield were recorded to ascertain response to integrated use of P sources. In both the year's, a combination of 25% poultry manure + 75% SSP recorded the maximum maize grain yield of 7.14 Mg ha^{-1} and 7.82 Mg ha^{-1}, respectively that was 48.13% and 62.91% respectively higher over control. This treatment also improved maize growth response over control and other treatments as well and realized higher dry matter accumulation due to more leaf area index and crop growth rate. A significantly positive relationship (r = 0.98) of maize grain yield with 1000-grain weight was recorded. A linear and positive correlation between grain yield and cumulative leaf area duration was noticed in both years. The results suggested that integration of organic and inorganic source of P can improve maize growth and enhance yield over sole application of inorganic source as a cost effective and environmentally benign nutrient management approach.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop of Pakistan after wheat and rice serving the purpose of food, feed and fodder in the country (Khaliq et al., 2010). It is sown on an area of 9.39 million hectares with total annual production of 3.341 million tons and national average yield is 3.56 tons per hectare (Anonymous, 2011). Maize having a C4 mode of carbon fixation shows rapid growth, producing large quantity of organic matter and has a higher demand for P. Maize is a phospho-positive crop and it accumulates phosphorous throughout the growing season with the highest uptake between third and sixth week of growth. Phosphorus accumulated in the leaves tends to reach a maximum about middle of the growing season and decreases as the plant matures.

In Pakistan, P is one of the major mineral nutrient needed by plants, but it is mostly inaccessible nutrient present is soils (Holford, 1997). Being the most likely to be fixed mineral nutrient in many cropping environments, P availability to plant is also very low. Application of inorganic phosphatic fertilizers over the years, continuously, leads to build phosphorous, leading to a negligible response. It is in fact a "finite and irreplaceable" mineral. Its known reserves, which are economically viable for exploitation, could run out in 60 to 100 years if current pace of its global consumption continues and without P there will be no agriculture (Osava, 2007). Like different arid regions of the world, about 80 to 90% soils of Pakistan are deficient in available P (NFDC, 2001). Soil fertility survey pointed out that, P after N is the most deficient nutrient in Pakistani soils (Memon, 1985). These soils are alkaline (pH>7.0) and mostly calcareous

($CaCO_3$>1.0%) in nature and are well known for fixation of added P. Attempts to alleviate phosphorus deficiency by adding phosphatic fertilizers are becoming expensive and ecologically unsound practice, as efficiency of added P fertilizer is as low as about 10% (Werft and Dekkers, 1996).

Despite of substantial fertilizer use, the crop yields in Pakistan are either stagnant or not increasing correspondingly presumably due to low fertilizer use efficiency (FUE). There are many problems related to the efficiency of chemical fertilizer, such as inappropriate method of fertilizer application (Ibrahim et al., 2011), physcio-chemical properties of soil (Ibrahim et al., 2012) inadequate supply or even unavailability of fertilizer at the time of requirement, adulteration and high cost (Ahmed, 1994). Synthesis of chemical fertilizers consumes a large amount of energy and capital. Moreover, continuous use of fertilizers creates potential polluting effect on the environment (Oad et al., 2004). However, organic farming, with or without chemical fertilizers seems to be a possible solution for the prevailing situations (Sarwar et al., 2010). The integration of organic nutrient sources with synthetic ones not only supply essential nutrients but also have some positive interaction with chemical fertilizers to increase their efficiency thereby reducing environmental hazards (Ahmad et al., 1996). Non-traditional wastes like poultry manure and press mud from sugar industry are of concern and need to be managed in environmental perspective. (Anon., 2007).

It is evident from different studies, recycling and addition of industrial and agricultural wastes to soil may enhance the efficiency of applied and native nutrients required by crops. Integration of filter cake as the organic waste with single super phosphate (SSP) in 2:1 ratio resulted in increased plant height, number of tillers per plant, straw and grain yield of wheat as well as P uptake by grain over control (Alam et al., 2005). Amujoyegbe et al., (2007) found highest grain yield and biomass of maize and sorghum with the combined application of inorganic fertilizer + poultry manure followed by inorganic fertilizer. In another study, application of poultry manure either alone or integrated with chemical amendments of P for maize, performed better than all amendments tested in laboratory trails (Mujeeb et al., 2010). Tahir et al. (2011) recommended that organic matter alone with synthetic fertilizers could be helpful for enhancing stagnant wheat grain yield Therefore, judicious and well-organized use of the existing land, nutrient fertilizers application, financial resources and recycling of organic wastes under field conditions is inevitable. Under the current circumstances, this field study was conducted to obtain knowledge regarding growth and yield responses of hybrid maize by applying different doses of organic and inorganic amendments of P in integrated form.

MATERIALS AND METHODS

Study pertaining to integrate phosphorus management in maize was carried out at Agronomic Research Area, University of Agriculture, Faisalabad (31.26^0 N latitude and 73.06^0 E longitude, 184.4 m above sea level a semi arid area), Pakistan, during the years 2008 and 2009. Trial was performed on a P deficient (6.3 ppm) sandy clay loam soil having pH, 7.9; EC, 1.48 (dS m^{-1}); organic matter, 0.69 (%); total nitrogen (0.04 %) and available potassium (1.40 ppm) where previous field history showed P deficiency. The mean temperature and relative humidity were 26.57, 26.37 and 60.2, 62.35 during the both seasons, respectively. The experiment was replicated thrice in randomized complete block design (RCBD) with a net plot size of 3 × $5m^2$. Poultry manure and press mud as organic and single superphosphate as inorganic phosphorus source were substituted in different ratios. Inorganic phosphorus source was substituted with 25, 50 and 75% organic source as per treatment.

Crop Husbandry

Seedbed was prepared by cultivating the soil for 2-3 times with tractor mounted cultivator each followed by planking. The maize hybrid FH-810 was sown with the dibbler and placed 2-3 seeds per hole with a row and plant spacing of 75 cm and 20 cm respectively, using seed rate of 20 kg ha^{-1}. The recommended dose of NPK@ 296:167:125 kg ha^{-1} was fulfilled in each treatment after deducting the amount of nutrients received through applied organic manures. Inorganic fertilizer sources of NPK were urea, single super phosphate and sulphate of potash respectively. Nitrogen was applied as urea. One third of N was applied at the time of sowing while remaining N was top dressed in two equal splits at knee height and at flowering stage. Each year, maize was harvested manually in the second week of November. All other cultural practices except those under study were kept as normal and uniform. The agronomic data of maize like plant height, 1000-grain weight and grain yield were recorded at maturity. Growth parameters LAI and CGR were recorded as proposed by Beadle (1987), while LAD were recorded as suggested by Hunt (1978). Growth parameters LAI, LAD, TDM and CGR were taken regularly at a fixed interval of 15 days. Five sampling were taken starting from 30 days after sowing to 90 days after sowing. All the data were analyzed by using the analysis of variance following STATISTICA 8.1 statistical package and difference among the treatment means were compared by applying least significant difference (LSD) test at $P = 0.05$ (Steel et al., 1997).

RESULTS

Agronomic parameters

Plant height (cm)

Data indicated significant ($P \leq 0.05$) effect of treatments on plant height. In both years, treatments T_5 (25% poultry manure + 75% SSP) and T_8 (25% press mud + 75% SSP) increased plant height over all other treatments followed by T_4 (50% poultry + 50% SSP) treatment. However both treatment (T_5 and T_8) were statistically at par regarding either year. Lowest plant height at 198.0 cm in 2008 and 202.10 cm in 2009 was obtained by the treatment T_1 (control).

1000-Grain weight

Significant ($P \leq 0.05$) differences regarding 1000-grain weight were recorded among treatments in both the years. Data showed that treatment T_5 (25% poultry manure + 75% SSP) significantly increased 1000-grain weight as compared to all other treatments. This was followed by treatment T_8 (25% pressmud + 75% SSP) which also enhanced 1000-grain weight over other treatment combinations in either year. Treatment T_1 (control) produced significantly lowest 1000-grain weight in either year.

Grain yield

Treatment T_5 (25% poultry + 75% SSP) significantly increased grain yield as compared to all employed treatments in both cropping seasons except, treatments T_8 (25% pressmud + 75% SSP) that was statistically at par with T_5 (25% poultry manure + 75% SSP) in 2008-09. Rest of the treatments behaved alike except T_1 where minimum grain yield was achieved in 2009. There was a positive and linear relationship between grain yield and total biomass in both the seasons.

Growth parameters

Leaf area index

Leaf area index (LAI) values steadily increased and reached maximum at 75 DAS in all the treatments; thereafter LAI declined in all the treatments and reached its minimum values at about 3-4 by 90 DAS. In both years, integrated phosphorus management treatments had a significant effect on LAI throughout the growth (Fig. 1a,b). The T_5 (25% poultry + 75% SSP) significantly enhanced LAI over all other treatments and this was followed by T_2 (recommended dose) and T_8 (25% pressmud + 75% SSP) which were statistically at par with each other in either year. Statistically, the minimum values were given by T_1 (control) treatment where no phosphorus was applied.

Leaf area duration

In both years, T_5 (25% poultry + 75% SSP) significantly increased LAD as compared to all other treatments (Table 2). This was followed by T_2 (recommended dose) and T_8 (25% pressmud + 75% SSP) treatments which increased LAD over other treatments in either year. Statistically, lowest LAD was given by T_1 (control) treatment where no phosphorus was added. Figure 2 depicts a linear and positive relationship between LAD and grain yield during both cropping seasons.

Total dry matter (TDM) accumulation increased throughout the growth in all treatments until maturity and responded positively to all the treatments (Fig 3a,b). In both years, T_5 (25% poultry + 75% SSP) treatment significantly increased TDM production as compared to all other treatments, except T_8 (25% pressmud + 75% SSP) treatment where the differences in TDM were statistically at par with each other.

Crop growth rate

Table 2 shows the effect of integrated phosphorus management treatments on mean crop growth rate (90 DAS-30 DAS). In both years, all organic and inorganic phosphorus treatments significantly enhanced mean CGR over control (T_1) treatments where no phosphorus

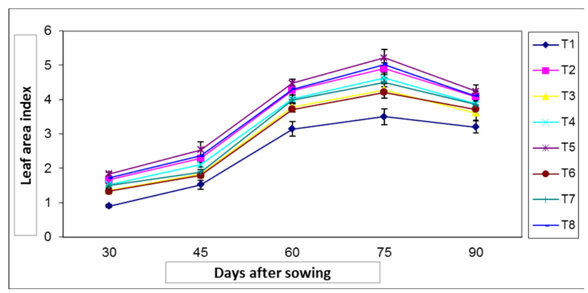

Fig. 1a: Periodic changes in leaf area index in response to affect integrated P sources during 2008.

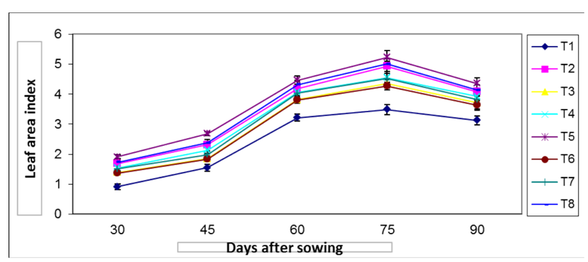

Fig. 1b: Periodic changes in leaf area index in response to affect integrated P sources during 2009.

Treatments: T_1: Control (without P); **T_2**: 100% P from inorganic source; **T_3**: 75% P from organic source (**PoM***) +25% P from inorganic source; **T_4**: 50% P from organic source (**PoM***) +50% P from inorganic source; **T_5**: 25% P from organic source (**PoM***) +75% P from inorganic source; **T_6**: 75% P from organic source (**PM****) +25% P from inorganic source; **T_7**: 50% P from organic source (**PM****) +50% P from inorganic source; **T_8**: 25% P from organic source (**PM****) +75% P from inorganic source; **PoM*=Poultry manure PM**=Press mud**

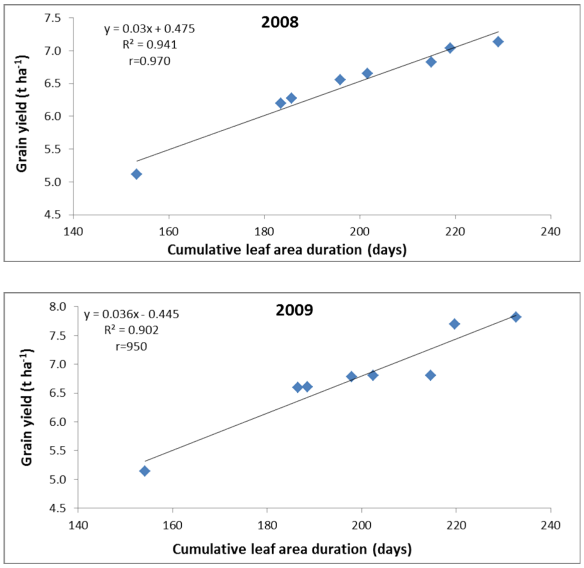

Fig. 2: Relationship between Cumulative leaf area duration (days) and grain yield (Mg ha^1) in maize during 2008 and 2009.

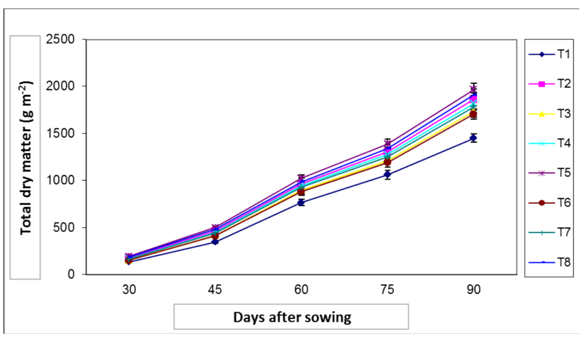

Fig. 3a: Periodic changes in total dry matter (g m^{-2}) in response to affect integrated P sources during 2008.

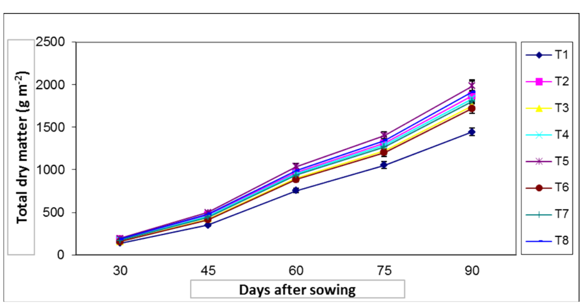

Fig. 3b: Periodic changes in total dry matter (g m^{-2}) in response to affect integrated P sources during 2009.

Treatments: T$_1$: Control (without P); **T$_2$**: 100% P from inorganic source; **T$_3$**: 75% P from organic source (**PoM***) +25% P from inorganic source **T$_4$**: 50% P from organic source (**PoM***) +50% P from inorganic source; **T$_5$**: 25% P from organic source (**PoM***) +75% P from inorganic source; **T$_6$**: 75% P from organic source (**PM****) +25% P from inorganic source; **T$_7$**: 50% P from organic source (**PM****) +50% P from inorganic source; **T$_8$**: 25% P from organic source (**PM****) +75% P from inorganic source **PoM*=Poultry manure PM**=Press mud; Total dry matter accumulation**

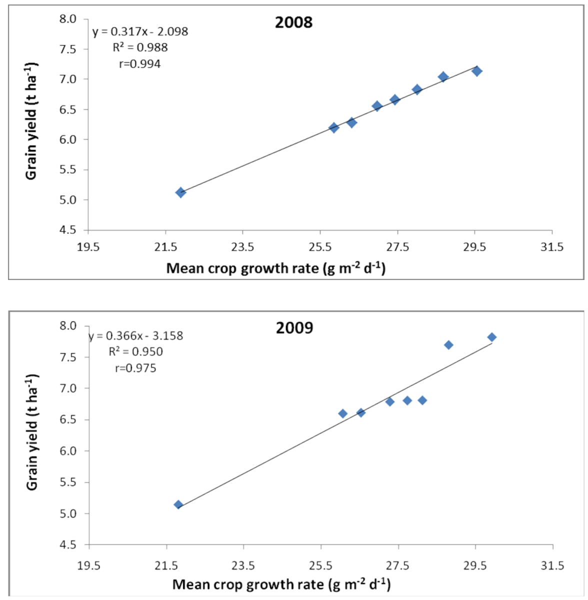

Fig. 4: Relationship between mean crop growth rate (g m^{-2} d^{-1}) and grain yield (Mg ha^{-1}) in maize during 2008, 2009

was added. Two years mean data showed that the maximum CGR was given by T$_5$ (25% poultry manure + 75% SSP) treatment as compared to other treatments. The differences in CGR were however, statistically at par and T$_6$ (75% press mud + 25% SSP) treatment gave statistically less values of CGR. The minimum CGR values were given T$_1$ (control) treatment. There is a strong and positive relationship between mean crop growth rate and grain yield (Fig. 4).

DISCUSSION

Agronomic parameters

Results of both years showed that significant increase was found in plant height, 1000-grain weight and grain yield with the addition of poultry litter in treatment T$_5$ (25% poultry + 75% SSP) as compared to other treatments, in both years. Boateng et al. (2006) reported maximum plant height where 4 t ha^{-1} poultry manure (PoM) was applied and it was mainly due to the reason of more availability of nutrients by PoM decomposition throughout the growing season. This study was also supported by Zhang et al. (1998) and Aziz et al. (2010). It might be due to supply of essential.

Table 1: Yield parameters of maize (*Zea mays* L.) as influenced by integrated phosphorus management

Treatments	Plant height (cm)		1000- grain weight (g)		Grain yield (Mg ha^{-1})	
	2008	2009	2008	2009	2008	2009
T_1	198.0 e	202.1 f	211.3 g	214.1 h	4.82 e	4.80 c
T_2	214.5 b	220.9 c	255.0 c	258.0 c	6.83 abc	6.81 b
T_3	209.9 cd	212.3 d	239.8 f	247.4 f	6.28 cd	6.61 b
T_4	214.4 b	223.9 b	249.7 d	253.3 d	6.66 abc	6.81 b
T_5	220.7 a	228.4 a	268.5 a	278.2 a	7.14 a	7.82 a
T_6	207.0 d	210.2 e	239.1 f	242.3 g	6.01 d	6.60 b
T_7	212.9 bc	220.1 c	247.5 e	251.9 e	6.55 bcd	6.79 b
T_8	218.8 a	227.6 a	260.3 b	269.0 b	7.04 ab	7.70 a
LSD 5%	*3.11*	*0.85*	*2.02*	*0.87*	*0.58*	*0.50*
S.E.M	1.026	0.279	0.667	0.286	0.191	0.165
Mean	212.0	218.1	246.4	251.7	6.42	6.74

S.E.M = standard error of mean; T_1: Control (without P); T_2: 100% P from inorganic source; T_3: 75% P from organic source (PoM*) +25% P from inorganic source; T_4: 50% P from organic source (PoM*) +50% P from inorganic source; T_5: 25% P from organic source (PoM*) +75% P from inorganic source; T_6: 75% P from organic source (PM**) +25% P from inorganic source; T_7: 50% P from organic source (PM**) +50% P from inorganic source; T_8: 25% P from organic source (PM**) +75% P from inorganic source; PoM* = Poultry manure; PM** = Press mud.

Table 2: Growth of maize (*Zea mays* L.) as influenced by integrated Phosphorus management

Treatment	LAI		LAD (days)		TDM (gm^{-2})		CGR ($gm^{-2}\,d^{-1}$)	
	2008	2009	2008	2009	2008	2009	2008	2009
T_1	3.50 f	3.49 e	153.3 e	154.1 e	1450.8 f	1446.1 f	21.9 e	21.8 e
T_2	4.90 bc	4.93 b	215.0 b	214.6 b	1860.7 bc	1870.8 bc	28.0 abc	28.1 bc
T_3	4.29 e	4.35 cd	185.8 d	188.5 d	1734.8 de	1749.2 de	26.3 d	26.5 cd
T_4	4.63 cd	4.56 c	201.6 c	202.4 c	1817.1 bcd	1837.6 bcd	27.4 bcd	27.7 bc
T_5	5.22 a	5.23 a	229.0 a	232.7 a	1968.4 a	1987.0 a	29.6 a	29.9 a
T_6	4.21 e	4.27 d	183.5 d	186.5 d	1707.1 e	1719.9 e	25.9 d	26.1 d
T_7	4.50 de	4.52 c	195.9 c	197.8 c	1785.2 cde	1805.8 cde	26.9 cd	27.3 bcd
T_8	5.02 ab	5.01 b	219.0 b	219.7 b	1908.9 ab	1915.0 ab	28.7 ab	28.8 ab
LSD 5%	0.31	0.22	6.55	7.23	96.5	92.9	1.6	1.6
S.e.m	0.101	0.072	2.16	2.38	31.83	30.61	0.53	0.52
Mean	4.54	4.54	197.9	199.5	1779.1	1791.4	26.8	27.0

LAI = Leaf area index; LAD = Leaf area duration; TDM = Total dry matter; CGR = Crop growth rate; S.e.m = standard error of mean; T_1: Control (without P); T_2: 100% P from inorganic source; T_3: 75% P from organic source (PoM*) +25% P from inorganic source; T_4: 50% P from organic source (PoM*) +50% P from inorganic source; T_5: 25% P from organic source (PoM*) +75% P from inorganic source; T_6: 75% P from organic source (PM**) +25% P from inorganic source; T_7: 50% P from organic source (PM**) +50% P from inorganic source; T_8: 25% P from organic source (PM**) +75% P from inorganic source; PoM*=Poultry manure; PM**=Press mud

nutrients especially N, P and K by the poultry manure which had been reported important in the determination of yield components (Sahoo and Panda, 2001; Udom and Bello, 2009). The increase in 1000-grain weight with addition of PoM could be due to balanced supply of food nutrients from PoM throughout the growing period (Garg and Bahl, 2008).

Early P uptake increases yield potential of the crops in both the cropping seasons by stimulating growth and development of plants as suggested by Mattar and Brown (1989). The increase in grain yield in treatment T_5 (25% poultry manure + 75% SSP) may be due to the supply of nutrients, especially N and P by the poultry manure which is known to be the most spectacular in plant growth and development. Similar results were reported by Silva et al., 2003; Boateng et al., 2006; Farhad et al., 2009; Udom and Bello, 2009. This increase in grain yield may also be connected with the positive increase associated with poultry manure on the yield components, especially the 1000-grain weight (Dekissa et al., 2008). Witt et al. (2006) observed that on-farm trials with maize clearly showed increase in yield and profitability through adopting integrated nutrient management system. Integration of organic nutrients sources with inorganic sources improved the bioavailability of residual soil phosphorus. Highest yield was achieved through the addition of TSP in combination with organic fertilizer, which had a highly positive effect on phosphorus uptake (Beri et al., 2002).

Growth parameters

Total dry matter production of a crop during the growth period is important for the determination of economic yield (Gallagher and Biscoe, 1978). Dry matter significantly increases with application of P which may be attributed to beneficial effects of organic and inorganic P applied to the maize crop. Result of both years, indicated that maximum total dry matter and crop growth rate at maturity were obtained in treatment T_5 (25% poultry manure + 75% SSP). Higher TDM production was due to the fact that crop nutrient requirement was adequately met throughout the crop growth. This in turn had increased yield attributing characters and grain yield of maize. The results were supported by Zalwadia and Raman (1994) and Iqbal et al. (2008) who evaluated the better response of fertilizer application along with manure and mulch, respectively. TDM production of a crop including maize is directly related to cumulative intercepted PAR during the growing period. Reduction of LAI in maize is the consequence of the delayed appearance of leaves on P deficient plants and reduction of their final surface area (Plenet et al., 2000). He also reported that lower biomass accumulation in the P deficient plants was mainly due to deficiency on leaf growth and its subsequent effect on PAR interception.

Integration of organic and inorganic sources resulted in higher achene and biological yield in sunflower that is attributed to more availability of nutrients and their uptake, which increased flowering, LAI, biomass and CGR (Munir et al., 2007). Differences in yield between different treatments can be explained by differences in their leaf area duration (LAD) in this study. In both years, T_5 (25% poultry manure + 75% SSP) significantly increase LAD than all other treatments, this yielded more TDM, CGR and grain yield. Variations in yield caused by T_5 and other organic manures were positively related with the cumulative LAD. Similar results were reported by others in many field crops including maize (Kumar et al., 1994). In this study, T_5 (25% Poultry manure+75% SSP) and T_8 (25% Pressmud+75% SSP) performed better as compared to other treatments combinations T_4 (50% Poultry manure+50% SSP), T_7 (50% Pressmud+50% SSP) and T_3 (75% Poultry manure+25% SSP), T6 that might be due to improvement in soil physio-chemical properties that resulted in better uptake of nutrients.

Conclusion

Results of this study confirmed that organic manures along with adequate proportion of synthetic fertilizer could be helpful in increasing stagnant grain yield of maize on sustainable basis. Based on findings of this experiment, It can be suggested that integrated use of P source (25% poultry manure + 75% SSP) is feasible for enhancing the maize growth and yield on sustainable basis under agro-climatic conditions of Faisalabad, Pakistan.

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